

SCANNING MOBILITY PARTICLE SIZER™ (SMPS™) SPECTROMETER DIFFUSION LOSS ALGORITHM

APPLICATION NOTE SMPS-001

Why Are Diffusion Losses Important in the SMPS™ Spectrometer?

To understand why we need a Diffusion Loss Algorithm, it is necessary to recall three facts:

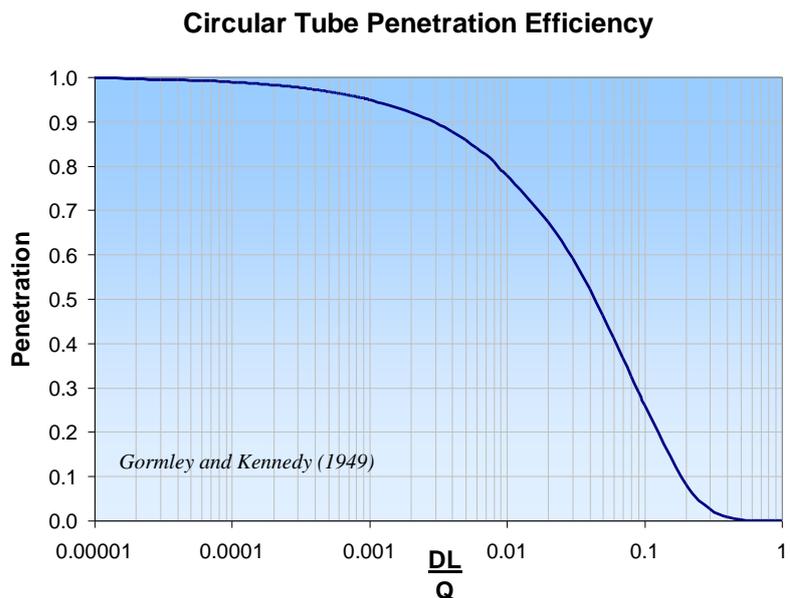
- 1) When aerosol particles collide with a surface they adhere due to van der Waals force, electrostatic force and surface tension.
- 2) Diffusion is the primary transport mechanism for particles smaller than 0.1 µm (100 nm).
- 3) The smaller the particle the more rapid the diffusion.

Thus, if an aerosol particle diffuses to the wall of its measurement flow path, there will be diffusion losses, and the measured size distribution will under represent small particles. Since the Scanning Mobility Particle Sizer™ (SMPS™) spectrometer measures particles in the size range of 2.5 nm–1000 nm, diffusion losses are unavoidable. They are however, quantifiable.

Diffusion losses are frequently characterized in terms of penetration (P) through a tube: $P = \frac{n_{out}}{n_{in}}$

Penetration is a function of the particle diffusion coefficient (D), length of the tube (L), and volumetric flow rate (Q). The Diffusion coefficient (D) is affected by temperature, gas medium, and particle diameter.

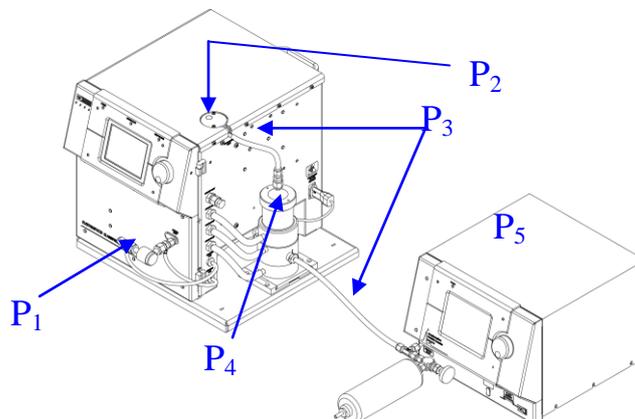
Note that the diffusion loss through a tube (for a fixed volumetric flow rate) is not a function of tubing diameter. The additional distance the particles must travel to the walls in a wider tube is offset by a longer residence time.



How Can You Characterize Diffusion Losses in the SMPS™ Spectrometer?

The Scanning Mobility Particle Sizing™ (SMPS™) spectrometer can be broken down into five different flow paths for which an aerosol penetration can be calculated.

- P₁ = Penetration through the impactor inlet
- P₂ = Penetration through the bi-polar neutralizer and internal plumbing
- P₃ = Penetration through the tubing to the Differential Mobility Analyzer (DMA) and CPC
- P₄ = Penetration through the DMA
- P₅ = Penetration through the CPC



Schematic of the component Scanning Mobility Particle Sizer™ spectrometer

The total penetration through the system is the product of the individual penetration values:

$$P_{total} = P_1 P_2 P_3 P_4 P_5$$

Determination of P₁: The penetration through the impactor assembly was determined experimentally using all three impactor sizes (0.0457 cm, 0.0508 cm, & 0.071 cm) and a variety of flow rates. P₁ is dependent on the Reynolds number so it is affected by the flow rate and the gas properties of the working gas. When using an impactor, it is important to stay within the recommended flow ranges to achieve the highest accuracy for the Diffusion Loss Algorithm.

Determination of P₂: The penetration through the internal passages of the Model 3080 Classifier (including the Model 3077/3077A neutralizer) was determined experimentally at a variety of flow rates. P₂ is a function of the particle diffusion coefficient and flow rate.

Determination of P₃: Penetration through the connecting tubing was calculated using Gormley and Kennedy's equations for penetration through a circular tube¹.

Determination of P₄: Penetration through each of the Differential Mobility Analyzers (Model 3085 and Model 3081) was determined using published data^{2,3,4} on the transfer functions for these DMAs and was also validated experimentally.

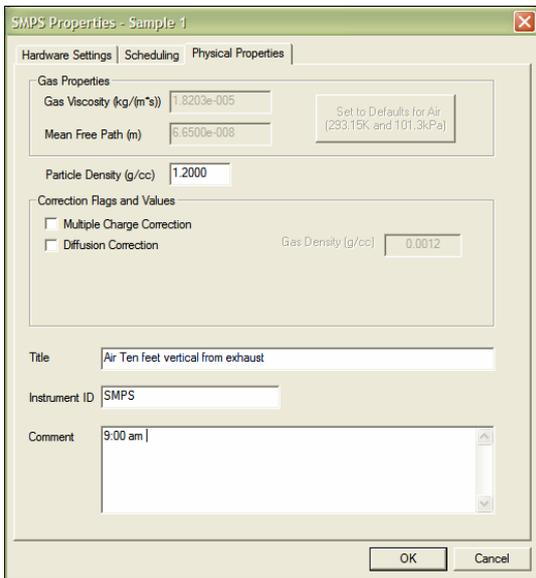
Determination of P₅: P₅ is the counting efficiency of the CPC and includes penetration inside the CPC, activation efficiency and optical detection efficiency.

Note: All of the experiments were performed using air at Standard Temperature & Pressure (STP) as the working gas. Since diffusion losses are a function of the particle diffusion coefficient (D) and D is a function of the working gas properties, the use of different working gases and/or conditions will result in an error in the calculated diffusion loss. It is possible to input gas properties in the software to increase the Diffusion Loss Algorithm accuracy, but other working gases and conditions have not been experimentally verified.

How Does It Work?

Simply open the SMPS™ Properties box in the Aerosol Instrument Manager® Software and under *Correction Flags and Values* check the *Diffusion Correction* box and enter the carrier gas density (the default value is the density of air).

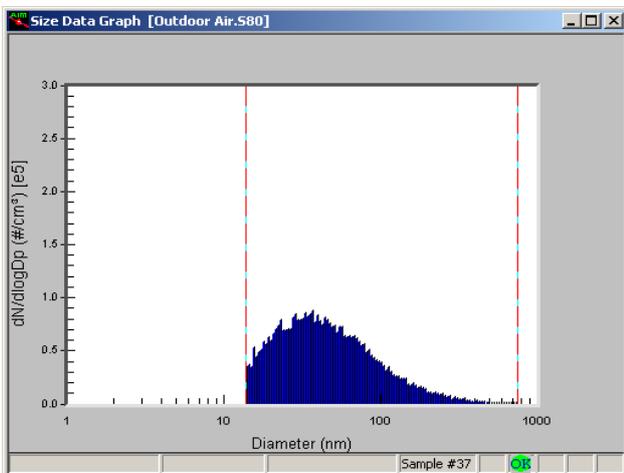
Note: The Algorithm can be toggled on and off and **can be applied to previously collected data** similar to Charge Correction.



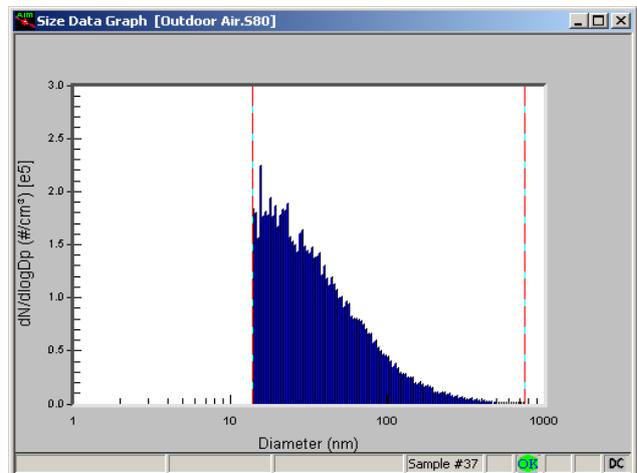
SMPS Properties box screen of Aerosol Instrument Manager™ software for the SMPS™ spectrometer.

Note: *The Diffusion Loss Algorithm was designed and validated for use with the Model 3080 Electrostatic Classifier platform only.*

Below is a Scanning Mobility Particle Sizer™ (SMPS™) Spectrometer data file of outdoor air illustrating the Diffusion Loss Algorithm. Diffusion losses are highly dependent on sample flow rate and particle size. This data was taken using a very low flow rate, so it is close to a “worst case scenario.”



without Diffusion Loss Algorithm



with Diffusion Loss Algorithm

When Should I Use the Diffusion Loss Algorithm?

Ultra-fine Particles: It is especially important to use the Diffusion Loss Algorithm when sizing aerosols smaller than 100 nm, since in this size regime diffusion becomes increasingly significant. The correction is negligible for aerosols larger than 100 nm.

Low Flow Rates: Sampling at low flow rates will also aggravate diffusion losses.

It is recommended to toggle the Diffusion Loss Algorithm and observe the magnitude of the correction whenever viewing data.

Free Upgrade

TSI is offering the Diffusion Loss Algorithm as a free upgrade to the Aerosol Instrument Manager™ software. To receive your upgrade please contact TSI at particle@tsi.com with the instrument model numbers and serial numbers of your component SMPS™ system.

Note: The Diffusion Loss Algorithm is **not** currently available for the Model 3034 Single-Box Scanning Mobility Particle Sizer™ Spectrometer.

References

¹Gormley, P. G. and Kennedy, M. (1949). "Diffusion from a stream flowing through a cylindrical tube". Proceedings of the Royal Irish Academy, **52A**, 163-169.

²Chen, D.-R., Pui, D. Y. H., Hummes, D., Fissan, H., Quant, F. R. and Sem, G. J. (1998). Design and Evaluation of a Nanometer Aerosol Differential Mobility Analyzer (Nano-DMA). *Journal of Aerosol Science* **29**: 497-509.

³Birmili, W., Stratmann, F., Wiedensohler, A., Covert, D., Russell, L. M. and Berg, O. (1997). Determination of Differential Mobility Analyzer Transfer Functions Using Identical Instruments in Series. *Aerosol Science and Technology* **27**: 215-223.

⁴Reineking, A. and Porstendörfer, J. (1986). Measurements of Particle Loss Functions in a Differential Mobility Analyzer (TSI, Model 3071) for Different Flow Rates. *Aerosol Science and Technology* **5**: 483-486.



UNDERSTANDING, ACCELERATED

TSI Incorporated – Visit our website www.tsi.com for more information.

| | | | |
|---------|------------------------|-----------|-----------------------|
| USA | Tel: +1 800 874 2811 | India | Tel: +91 80 67877200 |
| UK | Tel: +44 149 4 459200 | China | Tel: +86 10 8251 6588 |
| France | Tel: +33 4 91 11 87 64 | Singapore | Tel: +65 6595 6388 |
| Germany | Tel: +49 241 523030 | | |